United States
Department of
Agriculture

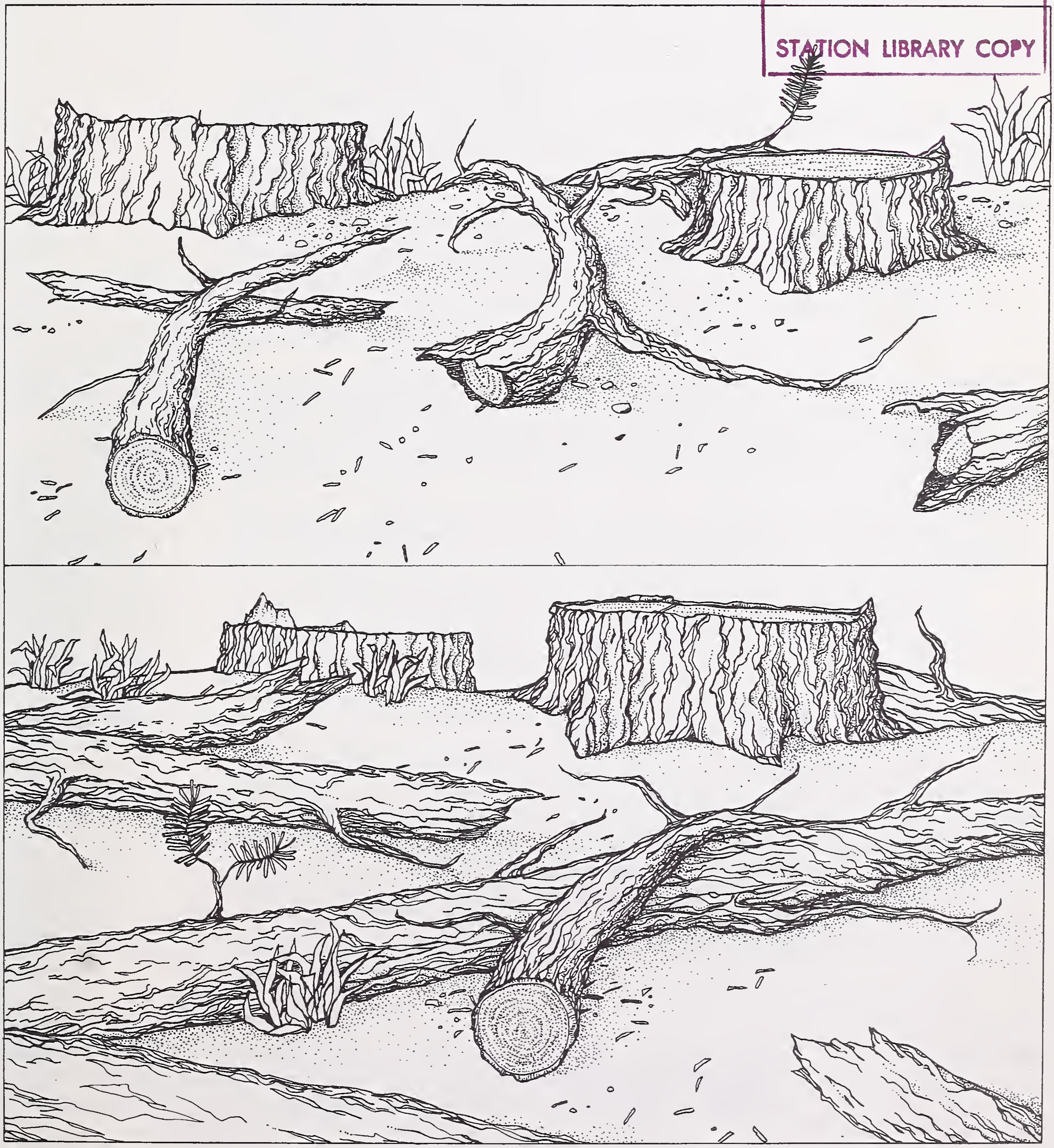
Forest Service

Pacific Northwest
Forest and Range
Experiment Station

Research Paper
PNW-338
June 1985

The Influence of Residue Removal and Prescribed Fire on Distributions of Forest Nutrients

S.N. Little and G.O. Klock



Authors

S.N. LITTLE is research forester, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, P.O. Box 3890, Portland, Oregon 97208. G.O. KLOCK is soil scientist, G.O. Klock and Associates, Wenatchee, Washington 98801.

Abstract

Little, S.N.; Klock, G.O. The influence of residue removal and prescribed fire on distributions of forest nutrients. Res. Pap. PNW-338. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1985.** 12 p.

The effects of two levels of residue removal (removal of all woody material larger than 15 x 180 cm and 10 x 120 cm) on the distribution of nitrogen and sulfur on the forest site and the added effects of postharvest prescribed fire on those distributions were studied at two sites in the Cascade Range in Oregon. Nutrients lost from increased removal of residue were small compared with nutrients removed in merchantable timber. Differences in the amount of nutrient capital removed during harvest between the two levels of residue removal amounted to 1 percent of the total site nitrogen and 4 percent of the total site sulfur. The amount of nutrient lost during fire depended not only on residue levels, but also on moisture content of residue and duff. At the site where both treatments had the same moisture levels, the unit with less residue removed by harvest lost 7 percent more nitrogen by the combination of harvest and prescribed burn. It appears that nutrient losses due to fire may be mitigated by increased residue removal.

Keywords: Nutrient loss, soil nitrogen, sulfur, residue treatments, prescribed burning, yarding residues.

Summary

Pressure is being put on all forest lands to maximize outputs from the current crop. Growing markets for alternative wood products has led to increased utilization of forest biomass, which has, in turn, led to concern over the ability to maintain forest productivity while meeting the increasing demand for biomass.

Maintaining productivity on a given harvest site depends on protecting soil integrity (including nutrient capital, soil structure, and soil stability), reducing competition from nontarget species, providing planting sites or adequate seedbed conditions, and protecting the future stand and adjacent timber from wildfire, pests, and disease. The harvest strategy and the treatments used to prepare a site for regeneration will affect all of these areas, particularly with respect to the amount of forest biomass left after harvest.

One specific area of concern is the effect on nitrogen and sulfur reserves of removal of increasing amounts of biomass combined with prescibed fire. This study looked at two levels of residue removal (removal of all woody material larger than 15 x 180 cm and 10 x 120 cm) and the added effects of postharvest prescribed fire on the distributions of nitrogen and sulfur. Two sites were chosen in the Cascade Range in Oregon: the Joule sale in the Willamette National Forest and the Blackeye sale in the Mount Hood National Forest. On all sites, nutrients removed in residue were small compared with nutrients removed in merchantable timber. Differences in the amount of nutrient capital removed during harvest between the two levels of residue removal amounted to 1 percent of the total site nitrogen and 4 percent of the total site sulfur.

The amount of nutrient lost during fire depended not only on residue levels, but also on moisture content of residue and duff. At Joule, differences between moisture levels overshadowed differences in residue loading before burn. At Blackeye, both treatments had the same moisture levels, and the unit with less residue removed by harvest lost 7 percent more nitrogen by the combination of harvest and prescribed burn. It appears that nitrogen losses during burning may be mitigated by increased residue removal, resulting in a net savings of nutrient capital. Attempts to quantify sulfur losses were largely unsuccessful.

Contents

Introduction

In the Pacific Northwest, concern is rising about the ability to maintain the productivity of forest lands with increased removal of residues and the use of prescribed fire for site preparation. Forest nutrients are lost from a site when residue is removed to meet demands for fuel and fiber. Nitrogen and sulfur, important plant nutrients which are often deficient in Pacific Northwest soils (Heilman 1981), are volatilized when slash is burned. This study explored the possibility that the amount of nitrogen and sulfur lost during a prescribed burn may be reduced by removing large residues before burning and hence reducing the duration of the burn.

Although the general effects of fire on soil and nutrient dynamics are known (Wells and others 1979), the combined effects of intensive harvesting and prescribed burning cannot be predicted. Harvesting woody residues leaves less large fuel on the unit to burn. Thus, nitrogen and sulfur losses from burning may be reduced because of lower fire intensity and duration. Although harvesting more wood from a site may decrease the need to burn for hazard reduction, because of the decrease in large fuel and compaction of the fine fuel, burning may still be the most cost-effective means of slash reduction to increase the number of available planting sites and to control unwanted brush. Knowledge of the effects of various combinations of harvest levels and prescribed burning on distributions of forest nutrients is needed for effective management.

The amount of forest residue remaining after a timber sale generally reflects the specified size of material that must be removed during harvest. Current specifications for USDA Forest Service sales west of the crest of the Cascade Range usually require the purchaser to remove all material larger than 20 cm in diameter by 310 cm in length. Because even smaller materials may be removed in the future to meet growing demands for fiber and fuel, a better understanding is needed of the relationship between size of residue left and the effects of burning. In a previous study (Little and others 1982), yarding to a minimum 15- by 180-cm specification significantly reduced the amount of residue on the site as well as the amount of duff consumed by the ensuing prescribed fire, as compared to that observed for a 20.3- by 310-cm specification. The objective of the study reported here was to determine the effects of two intensive harvest levels (15- by 180-cm and 10- by 120-cm yarding specifications) on the amount of nitrogen and sulfur remaining in residue, duff, and soil and the subsequent effects of prescribed fire on those nutrients.

Methods

The impacts of intensive harvest and prescribed fire were studied in two timber sales: Blackeye (Clackamas Ranger District, Mount Hood National Forest) and Joule (Lowell Ranger District, Willamette National Forest). The study sites in these sales were originally stands of old-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Four cutting units were divided in half (down slope) and logged to different yarding specifications.[1/] Units 20, 30, 11, and 22 were yarded to a 10 by 120 specification; units 2, 3, 12, and 21 were yarded to a 15 by 180 specification. Two pairs of units (2 and 20; 11 and 12) were chosen for nutrient and biomass analysis. Duff and fuel consumption were measured on all units.

[1/] Yarding of units was done as part of a study funded by the U.S. Department of Energy to assess the costs of harvesting different levels of residue (Adams 1983).

Preharvest Sampling

The amounts of nitrogen and sulfur in duff and soil were determined on twelve 0.08-ha fixed-radius plots on each of four units: 2, 20, 11, and 12. Plots were located on a randomly oriented grid of equilateral triangles to ensure uniform distribution among the sample plots. All duff was removed from two 0.1-m^2 areas at each plot, one 3 m north of plot center and one 3 m east of plot center. Duff included all of the forest floor above mineral soil (litter, fermentation, and humus layers). Mineral soil cores were extracted from the areas where the duff was removed at depths of 0-7.5 cm, 7.5-15 cm, 15-30 cm, and 30-60 cm. Samples were air dried and analyzed for total nitrogen by the micro-Kjeldahl method and for total sulfur by the high frequency induction furnace method (Black 1965). Descriptions of the soil chemical characteristics before and after harvest are shown in Appendix 1.

The amount of biomass and nutrients removed during harvest was determined using data from Adams (1983). Biomass removed in merchantable timber was calculated by species from gross scale volumes, specific gravity as sampled in the field, and board foot to cubic foot ratios as developed by Cahill (1984). All nonmerchantable material removed during harvest was weighed by species. Weights were corrected for moisture content using data collected at time of removal. Samples of wood and bark by species were taken for nitrogen and sulfur analyses. See Appendix 2 for calculations.

Postharvest Sampling

Residue (all woody material greater than 0.6 cm in diameter) was inventoried using the line intersect method (Brown 1974) on 1525 m of line for each unit to estimate fuel loading within ± 10 percent with 95-percent confidence (Pickford and Hazard 1978). Samples of residue from each species were taken at each study location and analyzed for nitrogen and sulfur concentrations in wood and bark.

The initial sample plots were used for the postharvest sample of duff and soil, with one sample taken 3 m south of plot center and one taken 3 m west of plot center. The same procedures used in the preharvest sampling were followed. Differences in amounts of nutrient capital between units were calculated as the difference by component of the average unit values.

Burning Conditions

All units were broadcast burned by the strip-headfire method. Just prior to ignition, 15 moisture samples were taken from the upper and lower halves of the duff layer and from residue 7.6 to 22.9 cm in diameter (thousand-hour fuel). Duff samples were ovendried at 72 °C and fuel samples were dried at 103 °C. The preburn fuel and duff conditions are listed in table 1.

Postburn Sampling

Duff consumption was estimated in two ways: by difference in duff weight and by the difference between measured depth of duff before and after burning. After burning, duff was sampled with two 0.1-m^2 samples taken from each of 12 plots on each unit. The difference in duff weight per hectare before and after burning was calculated as an average of plot measurements. These postburn duff samples were analyzed for nitrogen and sulfur. The duff depth on all sites far exceeded the depth consumed by fire. Because duff samples were collected before any significant leaching occurred, impact on soil was assumed negligible and no postburn soil samples were taken. Duff consumption was also measured as a reduction in duff depth according to the procedure developed by Beaufait and others (1977). Sixteen metal spikes were inserted in the soil 0.5 m apart on a grid at each of 25 plots in each unit. Twelve of the 25 plots were the same plots used to sample for soil and biomass capital.

Table 1--Preburn duff and fuel loadings, consumption, and moisture content

Unit (yarding spec.) 1/	Duff		Fuel >7.6cm		Fuel ≤7.6cm		Moisture content		
	Preburn depth	Depth consumed	Preburn loading	Loading consumed	Preburn loading	Loading consumed	Upper duff	Lower duff	Fuel >7.6cm
cm	- - - mm - - -		- - - - - - - - - kg/ha	- - - - - - - -			- - - percent - - -		
Joule:									
11 (10x120)	94	39	13.0	10.5	13.5	13.2	25	174	28
12 (15x180)	133	39	25.8	13.9	14.6	13.9	34	200	35
22 (10x120)	99	39	13.0	10.8	11.4	11.4	15	97	21
21 (15x180)	84	30	27.3	19.5	11.4	11.4	41	131	23
Blackeye:									
20 (10x120)	111	37	11.0	3.6	17.0	17.0	19	214	34
2 (15x180)	115	37	24.9	17.3	17.5	17.3	16	222	29
30 (10x120)	108	30	20.0	11.0	15.2	15.2	24	202	34
3 (15x180)	98	34	48.6	24.9	16.8	16.6	21	178	30

1/ Dimension of largest log to be left on the unit after harvesting.

Residue consumption was calculated by diameter reduction (Sandberg and Ottmar 1983). Percent consumption was calculated for residue diameter classes from measured reduction in diameters of logs caused by consumption. Postburn residue consumption was then computed as the product of preburn inventory and percent consumption for each residue diameter class.

Results and Discussion

Estimates of biomass, nitrogen, and sulfur for residue, duff, and soil are listed in table 2 for after harvest and after burn. Table 3 lists by components the changes in biomass, nitrogen, and sulfur caused by harvesting and burning.

Effects of Harvest

Losses of biomass, nitrogen, and sulfur during harvest reflected yarding specification on both sites. The difference between pairs of units in total above-ground biomass harvested was 104 Mg/ha for units 11 and 12 and 57 Mg/ha for units 2 and 20. The increased loss of nitrogen caused by the harvest of smaller material was 102 kg/ha at the Joule site and 61 kg/ha at the Blackeye site. This difference between units represents 5 percent of the nitrogen above mineral soil before harvest at unit 11 and 4 percent at unit 20. In both cases, this is only 1 percent of the total site nitrogen. The difference between units in loss of sulfur was 20 kg/ha at Joule and 13 kg/ha at Blackeye. This corresponds to 9 percent of the sulfur above mineral soil on unit 11 and 8 percent on unit 20, or 4 percent of the total sulfur on both sites.

Effects of Burning

At the Blackeye units, losses of biomass and nitrogen from burning were proportional to yarding specification. Unit 2, where less biomass was removed during harvest, lost 72 Mg/ha more biomass and 126 kg/ha more nitrogen than did unit 20.

At the Joule units, losses caused by consumption did not follow yarding specification. Unit 11 lost more biomass and nitrogen (15 Mg/ha and 319 kg/ha, respectively) than did unit 12. This inconsistency was due in part to the difference in fuel and duff moisture between these units. Unit 11 had drier fuel which enabled greater consumption. The loss of nitrogen from unit 12 appears to be quite low relative to

Table 2--Total biomass, nitrogen (N), and sulfur (S) by components after harvest and after burn (SE in parentheses)

Unit (yarding spec.) 1/	Component	After harvest			After burn		
		Biomass	N	S	Biomass	N	S
cm		- Mg/ha -	- - - - kg/ha - - - -		Mg/ha	- - - - kg/ha - - - -	
Joule 11 (10x120)	Residue	34 (6)	25 (4)	8 (1)	8 (1)	6 (1)	2 --
	Duff	244 (30)	1452 (168)	76 (9)	138 (14)	929 (94)	91 (10)
	Soil above 60 cm		4793 (252)	322 (16)		4793 (252)	322 (16)
Total		278 (36)	6270 (424)	406 (26)	146 (15)	5728 (347)	415 (26)
Joule 12 (15x180)	Residue	43 (3)	39 (3)	9 (1)	13 (3)	12 (2)	3 --
	Duff	195 (24)	995 (105)	60 (9)	113 (13)	799 (83)	69 (8)
	Soil above 60 cm		4154 (283)	340 (20)		4154 (283)	340 (20)
Total		238 (27)	5188 (391)	409 (30)	126 (16)	4965 (368)	412 (28)
Blackeye 20 (10x120)	Residue	34 (6)	29 (5)	8 (1)	12 (4)	10 (3)	3 --
	Duff	165 (21)	963 (132)	55 (8)	114 (41)	537 (186)	47 (12)
	Soil above 60 cm		2517 (91)	275 (11)		2517 (91)	275 (11)
Total		199 (27)	3509 (228)	338 (20)	126 (45)	3064 (280)	325 (23)
Blackeye 2 (15x180)	Residue	51 (6)	46 (6)	11 (1)	12 (2)	11 (2)	3 --
	Duff	199 (38)	1010 (145)	58 (10)	83 (17)	474 (69)	47 (8)
	Soil above 60 cm		1981 (89)	307 (12)		1981 (89)	307 (12)
Total		250 (44)	3037 (240)	376 (23)	95 (19)	2466 (160)	357 (20)

1/ Dimension of largest log to be left on the unit after harvesting.

the amount of biomass lost. We suspect that the sample size may not have been large enough at this site to assess nitrogen, because the difference in nitrogen concentrations in the duff between units 11 and 12 was not significant.

There appeared to be an increase in sulfur in the duff following the burn in units 11 and 12. This may reflect inputs of sulfur that were not volatilized from consumed woody fuel. Postburn sulfur levels were 20 percent less than preburn levels at units 2 and 20. It appears that either the field sampling or the chemical analyses, or both for sulfur were insufficient to determine the fate of sulfur at these sites.

Duff depth reduction and fuel consumption estimates are listed in table 1. There was no difference in depth reduction between paired units 11 and 12, and 2 and 20. Depth reduction at units 1, 3, and 30 increased with the amount of residue left on the site. Depth reduction was contrary to yarding specification on units 21 and 22, with 25 percent more depth reduction on 22, the unit with the more stringent specification. This was probably due to the high moisture content of the fuel and duff in unit 21. We suspect that moisture content played a more critical role than loading at these units.

Table 3--Changes in biomass, nitrogen, and sulfur caused by harvest and prescribed fire

Unit (yarding spec.) 1/	Component	Harvest			Burn		
		Biomass	N	S	Biomass	N	S
		Mg/ha	- - kg/ha - -		Mg/ha	- - kg/ha - -	
Joule 11 (10x120)	Harvest	-659	-600	-136	--	--	--
	Residue	+34	+25	+8	-26	-19	-6
	Duff	+135	+785	+38	-106	-523	+15
	Soil	--	+443	+46	--	--	--
Joule 12 (15x180)	Harvest	-555	-498	-116	--	--	--
	Residue	+43	+39	+9	-29	-27	-6
	Duff	+113	+328	+18	-82	-196	+9
	Soil	--	+293	-15	--	--	--
Blackeye 20 (10x120)	Harvest	-486	-450	-97	--	--	--
	Residue	+34	+29	+8	-23	-19	-5
	Duff	+69	+296	-1	-50	-426	-8
	Soil	--	+88	+53	--	--	--
Blackeye 2 (15x180)	Harvest	-429	-389	-88	--	--	--
	Residue	+51	+46	+11	-39	-35	-8
	Duff	+120	+461	+33	-116	-536	-11
	Soil	--	-124	+133	--	--	--

1/ Dimension of largest log to be left on the unit after harvesting.

Because the reduction data for duff depth as measured after harvest were not consistent with the biomass data from the nutrient samples, we could not estimate nitrogen loss for units 3, 30, 21, and 22. The inconsistency among data on depth reduction and biomass loss resulted from the destructive nature of the biomass sampling. Unlike the depth measurements, biomass samples could not be taken at the same place before and after burning. The sampling for duff depth reduction was much more intensive than sampling for biomass loss (400 samples vs 12 samples per unit). Given the high variability in duff depth over a unit, it appears that the sampling for biomass may have been insufficient.

Combined Effects of Harvest and Burning

The loss of total nitrogen from harvesting and burning was greater in unit 11 (1142 kg/ha) than in unit 12 (721 kg/ha) (table 3). This difference was probably due to differences in preburn fuel moistures as noted above. More nitrogen was lost from unit 2 (960 kg/ha) than from unit 20 (895 kg/ha). In this case, the loss of nitrogen during harvest due to removal of smaller material was more than compensated for by reduction in loss from burning caused by reduced fuel loading. On both sites, differences among units in the amount of sulfur lost was less than 3 percent of the total site sulfur before harvest.

Conclusions

In old-growth Douglas-fir/hemlock stands, the amount of nitrogen lost by removing additional biomass to the 10 by 120 specification appeared to be much less than the amount of nitrogen lost through harvest of merchantable material and prescribed fire. The results on units 20 and 2 indicated that there can be a net saving of nitrogen on units that are burned if they are logged to a closer specification. The results at Joule showed that moisture content plays a critical role in fuel and duff consumption and may overshadow any difference in preburn residue levels. Removing residue from a site may reduce the total amount of nitrogen lost from harvesting and burning for a given moisture content of fuel and duff. It may also increase the range of moisture levels under which a unit can be burned and yet achieve a limited amount of duff consumption and nitrogen loss.

The number of replicates was limited to two, and our results reflected only the conditions at the Blackeye and Joule study areas. We were able to show, however, that a measurable difference in nitrogen loss from fire can be achieved by increasing harvest specifications if moisture conditions are held constant. Further research is now underway to quantify the amount of nitrogen lost given different residue loadings and burning conditions.

Approximate Conversions to English Units

When you know	multiply by	to find
centimeters	0.394	inches
meters	3.281	feet
kilograms	2.205	pounds
hectares	2.471	acres
kilograms/square meter	0.205	pounds/square foot
kilograms/cubic meter	0.062	pounds/cubic foot
Mg/hectare (tonne/hectare)	0.446	tons/acre
cubic meters/hectare	14.291	cubic feet/acre

Literature Cited

Adams, T.C. Operational costs of harvesting logging residues for energy. Final Report to U.S. Dept. of Energy, Bonneville Power Administration IA DE-A151-81R000861. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1983.** 64 p.

Beaufait, William R.; Hardy, Charles E.; Fisher, William C. Broadcast burning in larch-fir clearcuts: the Miller Creek-Newman Ridge study. Res. Pap. INT-175, rev. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; **1977.** 73 p.

Black, C.A., ed. Methods of soil analysis, part II: chemical and microbiological properties. Monogr. 9. Madison, WI: American Society of Agronomy. **1965.** 1572 p.

Brown, James K. Handbook for inventorying downed woody material. Gen. Tech. Rep. INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; **1974.** 24 p.

Cahill, James M. Log scale conversion factors. *In:*Snellgrove, Thomas A.; Thomas D.; Bryant, Ben S., tech. eds. User's guide for cubic measurement. Seattle, WA: University of Washington; **1984:** 58-65.

Heilman, Paul. Minerals, chemical properties, and fertility of forest soils. *In:* Heilman, Paul E.; Anderson, Harry W.; Baumgartner, David M., eds. Forest soils of the Douglas-fir region. Pullman, WA: Washington State University Cooperative Extension Service. **1981:** 121-136.

Little, Susan N.; Ward, Franklin R.; Sandberg, D.V. Duff reduction caused by prescribed fire on areas logged to different management intensities. Res. Note PNW-397. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1982.** 8 p.

Pickford, Stewart G.; Hazard, John W. Simulation studies on line intersect sampling of forest residue. Forest Science. 24(4): 469-483; **1978.**

Sandberg, D.V.; Ottmar, R.D. Slash burning and fuel consumption in the Douglas-fir subregion. *In:* Proceedings 7th conference on fire and forest meteorology. 1983 April 25-28; Fort Collins, CO. Boston, MA: American Meteorological Society; **1983:** 90-93.

Snell, J.A. Kendall; Max, Timothy A. Bark-to-wood ratios for logging residue in Oregon, Washington, and Idaho. Admin. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1982.** 9 p.

Wells, Carol G.; Campbell, Ralph E.; DeBano, Leonard F. [and others]. Effects of fire on soils: a state-of-knowledge review. Gen. Tech. Rep. WO-7. Washington, DC: U.S. Department of Agriculture, Forest Service; **1979.** 34 p.

Appendix 1

Summary of Soil Capital Data

Data on soil nutrients and physical properties collected before harvest are listed in table 4. These data are presented to allow comparison with other study sites to determine the applicability of the results to other areas. Data following harvest are shown in table 5.

Table 4--Description of soil before harvest

Unit	Soil deptn	Bulk density	Organic matter	pH	Cation exchange	Total N	Total S	Exchangeable elements P	K	Ca	Mg
	cm	g/cm	kg/ha		meq/100g	kg/ha					
Joule 11	0-7.5	0.62	6.03	5.3	47.6	690	38	14.0	25	98	11
	7.5-15	.76	4.03	5.5	47.4	663	33	15.0	18	59	8
	15-30	.80	3.85	5.6	36.9	1180	72	24.9	33	90	13
	30-60	.87	2.74	5.7	34.6	1818	134	27.1	72	126	22
Total						4351	277	81.0	148	373	54
Joule 12	0-7.5	.62	5.11	5.0	54.7	767	52	17.8	30	63	14
	7.5-15	.70	3.98	5.3	47.9	536	45	12.9	17	35	7
	15-30	.80	3.19	5.6	39.3	1014	88	16.6	32	51	10
	30-60	.83	2.88	5.6	33.7	1517	170	30.4	65	63	14
Total						3834	355	77.7	144	212	45
Blackeye 20	0-7.5	.78	2.64	5.6	36.6	383	22	7.5	32	113	14
	7.5-15	.89	2.02	5.9	31.9	289	24	4.2	30	93	13
	15-30	.94	1.76	6.0	30.4	581	49	5.2	65	201	27
	30-60	1.04	1.54	6.1	29.8	1176	127	6.1	173	487	73
Total						2429	222	23.0	300	894	127
Blackeye 2	0-7.5	.86	2.21	5.5	33.7	327	31	5.0	37	86	13
	7.5-15	.96	2.00	5.8	28.6	384	31	3.7	40	90	15
	15-30	.96	1.63	6.0	27.5	489	57	4.4	73	148	35
	30-60	1.04	1.25	6.0	26.3	1005	119	4.9	179	342	98
Total						2205	238	18.0	329	666	161

Table 5--Description of soil after harvest

Unit	Soil depth	Bulk density	Organic matter	pH	Cation exchange	Total N	Total S	Exchangeable elements P	K	Ca	Mg
	cm	g/cm	kg/ha		meq/100g	- - - - - - - - - -		kg/ha	- - - -	- - - -	
Joule 11	0-7.5	0.71	5.96		60.8	657	47	9.1	16	115	17
	7.5-15	.81	4.82		52.9	646	40	6.5	16	78	11
	15-30	.85	4.16		45.4	1332	76	11.3	27	131	18
	30-60	.93	2.50		36.3	2159	160	14.3	53	167	30
Total						4794	323	41.2	112	491	76
Joule 12	0-7.5	.62	8.07		70.1	684	65	12.6	20	127	18
	7.5-15	.70	5.16		58.1	554	44	8.1	16	68	8
	15-30	.80	4.47		48.3	1089	77	13.7	19	71	11
	30-60	.83	3.58		42.3	1828	154	23.9	43	105	21
Total						4155	340	58.3	98	371	58
Blackeye 20	0-7.5	.76	4.94		50.2	467	39	5.0	25	274	21
	7.5-15	.90	2.80		38.7	333	29	2.5	24	197	18
	15-30	.95	1.93		31.9	569	62	3.1	45	330	36
	30-60	1.01	1.36		28.7	1147	145	3.8	120	620	103
Total						2516	275	14.4	214	1421	178
Blackeye 2	0-7.5	.79	3.86		36.4	365	39	4.6	32	154	21
	7.5-15	.96	1.67		27.2	308	35	3.0	31	136	22
	15-30	1.04	1.22		24.5	460	68	3.7	59	249	51
	30-60	1.09	.94		23.1	848	165	4.8	108	480	121
Total						1981	307	16.1	230	1019	215

Appendix 2

Calculation of Nitrogen and Sulfur Exported During Harvest

Adams (1983) determined the amount of wood removed from the Joule and Blackeye sales as part of his study on the cost of harvesting residue with conventional equipment. Data from his study include, by species, the gross scale of all merchantable material removed, green weights of all other wood removed, moisture content of residue removed, specific gravity of wood removed, and diameter of logs removed. Table 5 lists the data used to determine the total amount of biomass removed from the four units used in this study.

Nitrogen and sulfur concentrations determined from our data were then applied to the biomass estimates to obtain an estimate of the amount of nutrients removed during harvest (tables 6, 7, and 8). The amount of bark removed was determined using ratios developed by Snell and Max (1982). The amounts of nitrogen exported are slightly overestimated because their ratios assume that all bark is intact and nitrogen concentrations are higher for bark than for wood.

Table 6--Calculation of harvested biomass

Unit and species	Merchantable timber removed: Gross scale	Specific gravity 1/	Average diameter 1/	Ratio of BF/CF 2/	Weight from scale	Residue removed 1/	Total biomass removed
	board feet / cubic foot		cm	board feet / cubic foot	Mg/ha	Mg/ha	Mg/ha
Joule 11:							
Douglas-fir	112,625	0.40	109	7.25	434.8	105	540
Hemlock	17,225	.40	51	6.03	80.0	28	108
Redcedar	1,325	.33	51	6.03	5.0	--	5
True fir	1,325	.38	51	6.03	5.8	--	6
Total	132,500				525.6	133	659
Joule 12:							
Douglas-fir	99,624	.40	109	7.25	384.6	46	431
Hemlock	18,976	.40	51	6.03	88.1	33	121
Redcedar	--					3	3
Total	118,600				472.7	82	555
Blackeye 20:							
Douglas-fir	81,270	.40	84	7.00	325.0	101	426
Hemlock	8,127	.40	43	5.59	40.7	11	52
Redcedar	903	.33	36	5.50	3.8	4	8
Total	90,300				369.5	116	486
Blackeye 2:							
Douglas-fir	68,309	.40	84	7.00	273.1	65	338
Hemlock	13,168	.40	43	5.59	65.9	9	75
Redcedar	823	.33	36	5.50	3.8	12	16
Total	82,300				342.8	86	429

1/ Adams (1983).
2/ Cahill (1984).

Table 7--Calculation of nitrogen removed by harvest

Unit and species	Total biomass removed	Wood wt 1/ / bark wt	Wood: Wood removed	Wood: Nitrogen concen-tration	Wood: Nitrogen removed	Bark: Bark removed	Bark: Nitrogen concen-tration	Bark: Nitrogen removed	Total nitrogen removed
	Mg/ha	percent	Mg/ha	percent	kg/ha	Mg/ha	percent	- - - kg/ha - - -	
Joule 11:									
Douglas-fir	540	15	469.6	0.0892	393	70.4	0.1381	97	516
Hemlock	108	13	95.6	.0497	48	12.4	.2136	26	74
Redcedar	5	10	4.6	.0723	3	0.4	.2725	1	4
True fir	6	15	5.2	.0892	5	0.8	.1381	1	6
Total	659		575.0		449	84.0		125	600
Joule 12:									
Douglas-fir	431	15	374.8	.0892	312	56.2	.1381	78	412
Hemlock	121	13	107.1	.0497	53	13.9	.2136	30	83
Redcedar	3	10	2.7	.0723	2	.3	.2725	1	3
Total	555		484.6		367	70.4		109	498
Blackeye 20:									
Douglas-fir	426	15	370.4	.0892	312	55.6	.1381	77	407
Hemlock	52	13	46.0	.0497	23	6.0	.2136	13	36
Redcedar	8	10	7.3	.0723	5	0.7	.2725	2	7
Total	486		423.7		340	62.3		92	450
Blackeye 2:									
Douglas-fir	338	15	293.9	.0892	247	44.1	.1381	61	323
Hemlock	75	13	66.4	.0497	33	8.6	.2136	18	51
Redcedar	16	10	14.6	.0723	11	1.4	.2725	4	15
Total	429		374.9		291	54.1		83	389

1/ Snell and Max (1982).

Table 8--Calculation of sulfur removed by harvest

Unit and species	Wood: Wood removed	Wood: Sulfur concentration	Wood: Sulfur removed	Bark: Bark removed	Bark: Sulfur concentration	Bark: Sulfur removed	Total sulfur removed
	Mg/ha	percent	kg/ha	Mg/ha	percent	- - - kg/ha - - -	
Joule 11:							
Douglas-fir	469.6	0.0217	102	70.4	0.0053	4	106
Hemlock	95.6	.0286	27	12.4	.0047	1	28
Redcedar	4.6	.0176	1	0.4	.0028	0	1
True fir	5.2	.0217	1	0.8	.0053	0	1
Total	575.0		131	84.0		5	136
Joule 12:							
Douglas-fir	374.8	.0217	81	56.2	.0053	3	84
Hemlock	107.1	.0286	31	13.9	.0047	1	32
Redcedar	2.7	.0176	0	0.3	.0028	0	0
Total	484.6		112	70.4		4	116
Blackeye 20:							
Douglas-fir	370.4	.0217	80	55.6	.0053	3	83
Hemlock	46.0	.0286	13	6.0	.0047	0	13
Redcedar	7.3	.0176	1	0.7	.0028	0	1
Total	423.7		94	62.3		3	97
Blackeye 2:							
Douglas-fir	293.9	.0217	64	44.1	.0053	2	66
Hemlock	66.4	.0286	19	8.6	.0047	0	19
Redcedar	14.6	.0176	3	1.4	.0028	0	3
Total	374.9		86	54.1		2	88

Little, S.N.; Klock, G.O. The influence of residue removal and prescribed fire on distributions of forest nutrients. Res. Pap. PNW-338. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1985.** 12 p.

The effects of two levels of residue removal (removal of all woody material larger than 15 x 180 cm and 10 x 120 cm) on the distribution of nitrogen and sulfur on the forest site and the added effects of postharvest prescribed fire on those distributions were studied at two sites in the Cascade Range in Oregon. Nutrients lost from increased removal of residue were small compared with nutrients removed in merchantable timber. Differences in the amount of nutrient capital removed during harvest between the two levels of residue removal amounted to 1 percent of the total site nitrogen and 4 percent of the total site sulfur. The amount of nutrient lost during fire depended not only on residue levels, but also on moisture content of residue and duff. At the site where both treatments had the same moisture levels, the unit with less residue removed by harvest lost 7 percent more nitrogen by the combination of harvest and prescribed burn. It appears that nutrient losses due to fire may be mitigated by increased residue removal.

Keywords: Nutrient loss, soil nitrogen, sulfur, residue treatments, prescribed burning, yarding residues.

The **Forest Service** of the U.S. Department of Agriculture is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives — as directed by Congress — to provide increasingly greater service to a growing Nation.

Pacific Northwest Forest and Range
Experiment Station
319 S.W. Pine St.
P.O. Box 3890
Portland, Oregon 97208